What Is Life? – Reconsidered*

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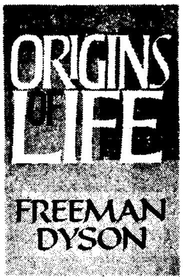

Origins of Life
by Freeman Dyson
Cambridge University Press, 1985.

The problem of the origin of life is a very old one. While there have been some distinguished supporters for theories suggesting extra-terrestrial origin and subsequent transport of life to earth, the remaining scientific community has built up a progressively more convincing, if more complex, reconstruction of the possible events leading to the origin of life on primitive earth. As it happens so often, our present beliefs about the origin of life on earth go back to Charles Darwin in whose inimitable style "But if (and oh, what a big if) we could conceive in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, etc., present, that a protein compound was chemically formed ready to undergo still more complex changes, at the present day such matter would be instantly devoured or absorbed, which would not have been the case before living creatures were formed."

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More sophisticated theories embodying this basic idea were formulated by A I Oparin and by J B S Haldane in the 1920's. The experimental demonstration of abiological synthesis of complex biological molecules including amino acids in simulated primordial earth conditions by Stanley Miller in 1953 gave a major boost to these theories. Since then there have been innumerable extensions and modifications of the Miller experiment and impressive theoretical leaps into imagining how these chemically formed molecules might have got together to form a primitive cell. The discovery of DNA as the genetic material and the advent of molecular biology quite naturally shifted attention to the pre-biotic chemical synthesis of nucleic acids and their precursors and more importantly, to the possible ways in which primitive nucleic acids may have undergone some crude form of replication without the aid of enzymes. It was soon realized that RNA rather than DNA was likely to have been the more primitive carrier of genetic information. The problem of the non-enzymatic synthesis and replication of RNA in the pre-biotic world has thus virtually become synonymous with the problem of the origin of life.

In the delightful little book under review, which is based on his Tarner lecturers at Trinity College, London, the well-known physicist Freeman Dyson brings in a breath of fresh air. Dyson correctly attributes the present-day replication-centered pre-occupation of molecular biology to Erwin

Schrödinger's advice to biologists to investigate the molecular structure of the gene. But then why did Schrödinger call his book *What is life?*. Because, says Dyson, Schrödinger equated life with 'replication' and neglected to worry about 'metabolism' (perhaps wisely at that time, as Mukunda has argued in the accompanying review of Schrödinger's book). But Dyson argues convincingly that the time has now come to once again ask "What is life?" and focus this time around on 'metabolism' rather than replication.

Origins of Life is full of virtues. It has new ideas, provides a plausible solution to a long-standing problem and even has a mathematical model whose results are not only largely consistent with known facts but also suggest new approaches to experimentalists. Dyson's style makes the book a pleasure to read; he never overstates his case and always cautions the reader on the boundary between fact and hypothesis. In addition Dyson does a masterly job in setting his hypothesis in a historical and philosophical perspective. All this in just 77 pages – what more can one ask for?

Dyson's main thesis is that life originated twice, not just once. First he makes a very convincing case for the distinction between what he calls *replication* (= nucleic acid) and *metabolism* (= protein). Borrowing on von Neumann's analogy, he equates nucleic acid to *software* and protein to *hardware* and reminds us that hardware logically comes before software. So in Dyson's hypothesis (he is not willing to call it a theory), metabolism or proteins evolved first, and once this crude hardware was available, nucleic acid or the software evolved in a second step. In today's organisms nucleic acids are needed for protein synthesis and proteins are needed for nucleic acid synthesis. So which came first, the chicken or the egg? Dyson clearly prefers the chicken (= metabolism or protein) for step one and argues that a primitive form of life consisting only of protein must have arisen first, growing, metabolising and reproducing in some crude fashion before nucleic acids came along in step two. Apart from its logical reasonableness, this sequence makes sense of what has long been an acute embarrassment to experimentalists. The accumulated wisdom of the variations of the Stanley Miller experiment has been that amino acids are formed readily in simulated pre-biotic conditions but nucleic acid bases, let alone nucleotides, are much harder to come by. If only proteins needed to have been produced pre-biotically and nucleic acids originated inside primitive 'cells' already containing proteins, the experimental findings make perfect sense.

But how did the primitive 'protein' organism get along without nucleic acids? Dyson recognises that they must have been beyond the reach of Darwinian natural selection because they could not have reproduced with any level of precision. He therefore uses Kimura's neutral theory of evolution to deal with these primordial 'cells'. But it is Dyson's treatment of the subsequent evolution of RNA as a parasite that is most appealing in the context of present-day evolutionary biology. If RNA (or DNA) is the software it can exist as a parasite on the hardware without contributing anything in return. That is precisely what most present-day viruses do. The primitive RNA must have started off as a parasite until the protein-based life "learned to make use of the capacity for exact replication which the chemical structure of RNA provided" and "The primal symbiosis of protein-based life and parasitic RNA grew gradually into a harmonious unity, the modern genetic apparatus".

Recent findings that RNA molecules can sometimes have enzymatic properties and can possibly catalyze their own replication have led some biochemists to believe that the chicken and egg problem has finally been solved in favour of RNA but I would hazard a guess that such a conclusion is too premature – the logic in Dyson's arguments (in favour of protein) is so compelling that we need to tread here with caution. At the very least, more biochemists should read Dyson

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The way to solve the conflict between human values and technological needs is not to run away from technology. That's impossible. The way to resolve the conflict is to break down the barriers of dualistic thought that prevent a real understanding of what technology is – not an exploitation of nature, but a fusion of nature and the human spirit into a new kind of creation that transcends both. When this transcendence occurs in such events as the first airplane flight across the ocean or the first footstep on the moon, a kind of public recognition of the transcendent nature of technology occurs. But this transcendence should also occur at the individual level, on a personal basis, in one's own life, in a less dramatic way.

Robert M Pirsig